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VOL. 27, SEC. D. FEBRUARY, 1949 NUMBER 1

THE WEIGERT-PAL METHOD FOR PARAFFIN-EMBEDDED MATERIAL

I. BULK STAINING AND STAINING OF PARAFFIN SECTIONS[1]

BY J. A. COLIN NICOL[2]

WITH THE ASSISTANCE OF FRANK PAUL[3]

Abstract

Three methods of staining myelin sheaths by the Weigert-Pal method in paraffin sections are compared. Hyomandibular nerves and spinal cord of the ratfish (*Hydrolagus colliei*) and tibial and peroneal nerves of the white rat were used. Fixation and mordanting comprised: 10% neutral formol, 48 hr.; 2.5% potassium bichromate at 37° C., 12 days; gliabeze, 2 days. The tissue was washed for 24 hr., and stained for 24 hr. either in bulk, or while in paraffin sections, or on the slide after coating with celloidin. Kulschitzky's haematoxylin, freshly prepared and artificially ripened, was used for staining. Differentiation was carried out by Pal's method. Bulk staining gave most satisfactory results, with the other methods as second and third alternatives, respectively. Treating the sections with safranin and dehydrating in dioxan was found to give a satisfactory counterstain.

Introduction

The Weigert method for staining myelin sheaths of nerve fibers involves treating the tissue with potassium bichromate, which acts as a mordant, then overstaining with haematoxylin to form a lake, and differentiating the sections. The bichromate is followed by a secondary mordant containing chrome and copper salts, which enhance the stain. Sections are usually cut in celloidin (1, 4). Also the method has been employed with paraffin embedding and, in common with other workers, we have obtained very good pictures of myelin sheaths in paraffin sections (8, *et al.*). One serious drawback to the paraffin method, however, is that sections frequently become detached from the slides during the prolonged period of immersion in the staining solutions, particularly if alkaline media are employed. This difficulty may be obviated by coating the sections with celloidin. We have found that better preparations may be obtained by these two methods: (*a*) staining the nerve in bulk after mordanting; (*b*) staining the sections while they are still in paraffin.

[1] *Manuscript received September 3, 1948.*
Contribution from the Department of Zoology, University of British Columbia, Vancouver, B.C.

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[The December issue of Section D (Can. J. Research, D, 26 : 329-357. 1948.) was issued January 26, 1949.]

Bulk staining with alum haematoxylin is well known and the principle as we have employed it involves nothing radically new. Staining of material in paraffin has also been used by several workers. Baker (2) has shown that certain refractory materials may be softened by soaking the paraffin block of tissue in a glycerine–water–alcohol mixture that penetrates the surface tissue. Copeland (3) has obtained surface staining by placing the paraffin block in a solution of haematoxylin. Several workers have shown that sections in paraffin may be stained by floating the sections on the surface of the staining solution (5, 10, *et al.*) and Robb-Smith (7) has recommended this expedient for a silver impregnation method employing an alkaline solution that tends to lift sections from the slide. We have tried several variants and have found the following procedures satisfactory.

Materials and Methods

The material used comprised the hyomandibular nerve and spinal cord of the ratfish (*Hydrolagus colliei*) and the tibial and peroneal nerves of the white rat. Material was fixed for two days in 10% formol (4% formaldehyde), which was neutralized by the addition of powdered chalk. Subsequent procedure was as follows.

A. *Mordanting*

1. The nerves were placed in 2.5% potassium bichromate at 37° C. for 12 days.
2. They were transferred to a solution of gliabeze at room temperature for 48 hr. Gliabeze consists of chromium fluoride 2 gm., copper acetate 5 gm., glacial acetic acid 5 cc., and 100 cc. of distilled water.
3. Material was washed 24 hr. in running tap water.

B. *Staining of Sections*

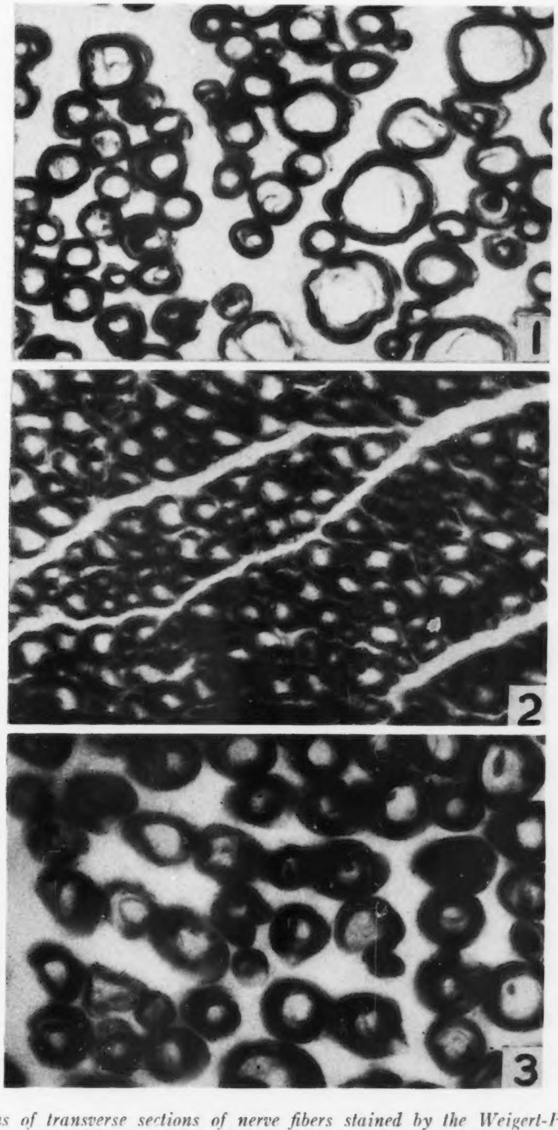
The nerves were dehydrated in alcohols, cleared in cedarwood oil, embedded in paraffin wax (melting point about 56° C.), and sectioned at 15μ to 20μ.

Kulschitzky's acid haematoxylin, made up as follows, was used for staining: dissolve 1 gm. of haematoxylin in 10 cc. of 95% ethanol. Add 88 cc. of distilled water and 2 cc. of glacial acetic acid. Ripen for immediate use by the addition of 0.1 gm. of sodium iodate. Filter.

1. Sections were deparaffinized, coated with celloidin, hydrated, and incubated in the haematoxylin solution at 37° C. for 24 hr. They were then washed about 30 min. in running tap water and differentiated.
2. Sections, still in paraffin, were floated on the surface of the haematoxylin solution and placed in an incubator at 37° C. for 24 hr. They were removed then to a large volume of tap water, which washes off the stain, and mounted on slides. After drying, sections were deparaffinized, hydrated, and differentiated.

C. *Bulk Staining*

Mordanted nerves were placed in Kulschitzky's haematoxylin at 37° C. for 24 hr. and 48 hr. After washing for five hours in tap water they were



Photographs of transverse sections of nerve fibers stained by the Weigert-Pal method. Magnification ×560. FIG. 1. *Hyomandibular nerve of Hydrolagus colliei. Section stained while in paraffin. Fig. 2. Tibial nerve of rat. Nerve stained in bulk.* FIG. 3. *Hyomandibular nerve of Hydrolagus colliei. Section coated with celloidin and stained on the slide.*

embedded and sectioned as above. Sections were mounted, deparaffinized, hydrated, and differentiated.

D. *Differentiation*

This was done by Pal's method of alternate baths of potassium permanganate and oxalic acid – sodium sulphite solutions (4).

E. *Subsequent Treatment*

Sections were washed for one hour in running tap water and either mounted directly or counterstained with safranin (safranin rein, Grübler's). Safranin washes out very quickly in alcohols but may be retained by dehydrating the sections with dioxan, in which it is only slightly soluble (6, 9). Our procedure is as follows: stain 30 sec. in a 1% solution of aqueous safranin. Wash 5 min. in running tap water. Dehydrate in two changes of dioxan for 5 and 2 min. respectively. Clear in xylol and mount.

Results and Conclusions

Satisfactory preparations were obtained by all of the above methods (Figs. 1 to 3). Myelin sheaths appeared dark blue-black against a colorless background of connective tissue, or against a red background if the sections were counterstained. Without celloidin coating, however, most of the sections were lost from the slide. With a celloidin coating, and many sections on the slide, there is often a considerable variation in the degree of staining between different sections. This difficulty apparently arises through slight variations in the thickness of the celloidin film affecting diffusion times in the permanganate bath. With sections stained in paraffin some difficulty was encountered in obtaining perfectly flat sections owing to imbibition of water and swelling of the tissue. The procedure also is slightly more time-consuming than bulk staining. With this material bulk staining for 24 hr. gave uniformly good coloration of myelin sheaths. The latter method is recommended for peripheral nerves, with staining of sections in paraffin and staining of mounted sections as second and third alternatives. Small pieces of central nervous tissues may also be stained by the above methods.

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THE WEIGERT-PAL METHOD FOR PARAFFIN-EMBEDDED MATERIAL

II. DECALCIFICATION OF MATERIAL CONTAINING BONE[1]

By J. A. Colin Nicol[2]

With the Assistance of Frank Paul[3]

Abstract

Several methods were tried of decalcifying material to be stained by the Weigert-Pal method for myelin sheaths. Pieces of the tail of a teleost, *Porichthys notatus*, and peroneal and tibial nerves of the white rat were used. The following procedure was found to give good staining of myelin sheaths after treatment with acid. Fix tissue in 10% neutral formol. Transfer to 5% trichloroacetic acid for five days. Wash one hour, and mordant in potassium bichromate followed by gliabeze. Prepare paraffin sections, stain with Kulschitzky's haematoxylin, and differentiate by Pal's method.

Introduction

In using the Weigert-Pal method for the nervous system of small animals we have found it necessary to stain the nerves along with the contiguous tissue and to decalcify the bone. Having discovered no satisfactory technique in the literature we have tried several procedures, which are here described. Decalcification by trichloroacetic acid as reported in Bolles Lee § 601 (5) has been used. On empirical grounds the treatment of nervous tissue with acid should present no difficulty in carrying out a Weigert stain since Holmes (4) has reported that the addition of 5% acetic acid to the formol fixative preserves myelin sheaths for long periods (nine months). We have also tried the effects of adding calcium and cadmium to the various solutions, as recommended by Baker (1) for the preservation of lipides.

Materials and Methods

Two sources of tissue were used. (1) Blocks of the tail of the midshipman (*Porichthys notatus*), a teleost fish. These were 0.5 to 1 cm. cubes containing vertebral column, spinal cord, spinal nerves, haemal canal, and muscle. (2) Peroneal and tibial nerves of the white rat. These were used to provide an independent source of information concerning the action of the decalcifying agent on nerve fibers since the staining of their myelin sheaths by a routine method had already been determined. The fish tissue was fixed in 10% neutral formol for two months; the rat nerves were fixed for two days, in part in 10% neutral formol, in part in 10% neutral formol with the addition of 1 gm. of calcium chloride per 100 cc. Subsequent treatment consisted of

[1] *Manuscript received September 3, 1948.*
Contribution from the Department of Zoology, University of British Columbia, Vancouver, B.C.

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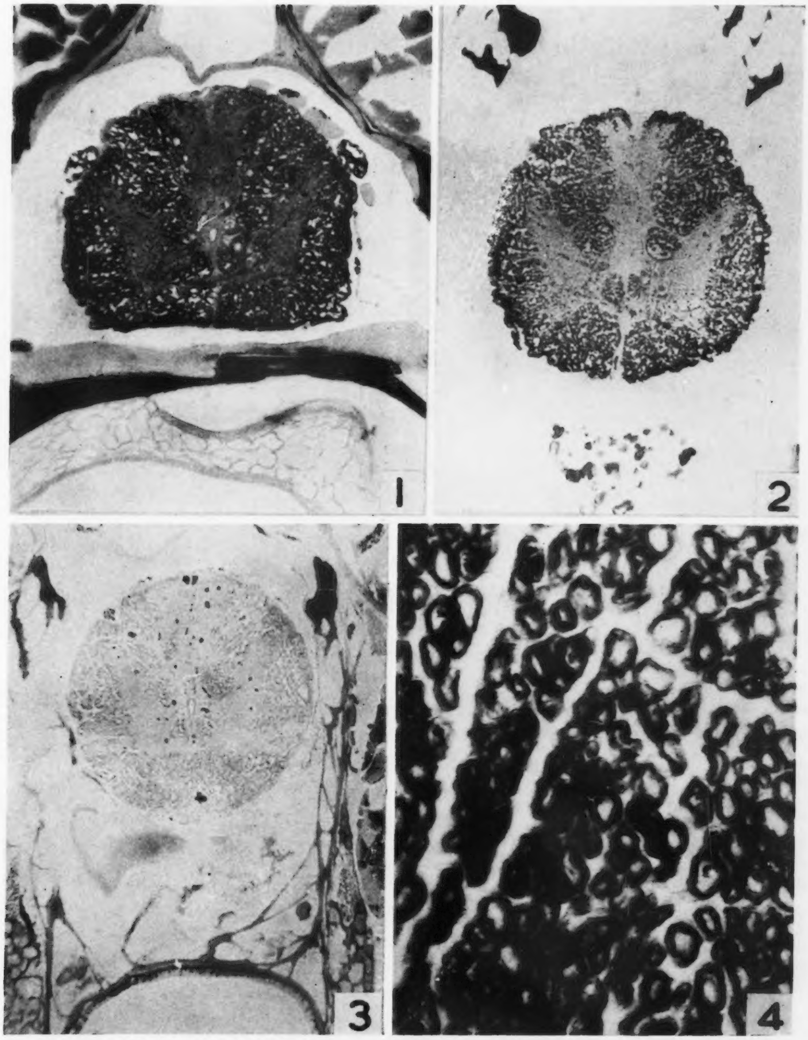

Photographs of transverse sections of nervous tissue. Weigert-Pal stain.
FIGS. 1 to 3. *Spinal cord of Porichthys notatus. Magnification ×68.* FIG. 1. *Trichloroacetic acid followed by mordant. Counterstained with safranin.* FIG. 2. *Trichloroacetic acid—Ca-Cd followed by mordant.* FIG. 3. *Mordant followed by trichloroacetic acid.* FIG. 4. *Tibial nerve of white rat. Trichloroacetic acid followed by mordant. Magnification ×700.*

treating a portion of each material with the decalcifying agent, trichloroacetic acid, before mordanting; the remainder with trichloroacetic acid after mordanting.

Mordanting, staining, and differentiation were carried out in the manner described in the previous paper of this series.* The procedure was as follows.

A. *Decalcification Before Mordanting*

Tissues were transferred from the formol fixative to: (1) 5% trichloroacetic acid; (2) 5% trichloroacetic acid containing 1 gm. of calcium chloride per 100 cc.; (3) 5% trichloroacetic acid containing 1 gm. of calcium chloride and 1 gm. of cadmium chloride per 100 cc. for five days. They were then washed for one hour and mordanted. After paraffin embedding, sections were coated with celloidin, stained with Kulschitzky's haematoxylin, and differentiated by Pal's method.

B. *Decalcification After Mordanting*

Tissues were mordanted, washed, and transferred to the three solutions of trichloroacetic acid, described in Section A, for five days. They were then washed one hour and embedded in paraffin. Sections were coated with celloidin, stained with Kulschitzky's haematoxylin, and differentiated by the Pal method.

Some sections were counterstained with safranin by the procedure described in the previous paper.

Results and Conclusions

Material treated with trichloroacetic acid before mordanting gave good coloration of the myelin sheaths, which appeared dense blue-black. There was some background stain in the center of muscle fibers, and ossein and fatty cells were stained. Connective tissue, however, was unstained (Figs. 1 to 4). The method gives clear-cut demarcation of myelin sheaths in the nerve fibers. In material treated with trichloroacetic acid after mordanting the stain is weak and diffuse and washes out in the alcohols during dehydration. Weak acids have been used by several workers to remove chrome salts from sections that have been fixed in Helly's fluid or postchromed (2, 3) and it is probable that the trichloroacetic in this material has diminished or removed the chrome and copper mordant. No significantly better results were obtained by adding calcium and cadmium to the formalin and trichloroacetic acid. However, Pal's method of differentiation cannot be timed exactly from slide to slide and makes an exact comparison of staining intensity of doubtful value. For larger pieces of tissue requiring longer periods of decalcification it probably would be advantageous to add calcium and cadmium salts to reduce loss of lipides. We conclude that decalcification may be carried out successfully on tissue to be stained by the Weigert-Pal method. After preliminary fixation in 10% neutral formol, the tissue may be decalcified with 5% trichloroacetic acid, then mordanted, stained, and differentiated by the Pal method.

* *Can. J. Research, D, 27 : 1-3. 1949.*

Acknowledgments

This work was carried out during an investigation of the autonomic nervous system of fish. We acknowledge with thanks financial assistance received from the National Research Council of Canada for this investigation.

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POPULATION PHENOMENA IN CERTAIN GAME FISHES OF LAKE SIMCOE, ONTARIO, AND SOME EFFECTS UPON ANGLING RETURNS. PART I. THE SMALLMOUTH BASS, *MICROPTERUS DOLOMIEU* LACÉPÈDE[1]

By James R. Westman[2] and Charlotte B. Westman

Abstract

The varying susceptibility and availability of game fish populations to angling methods is seldom approached by modern scientific procedure, despite the fact that angling returns are generally accepted as reliable indices of population densities. Lake Simcoe—Ontario's fourth largest lake—afforded an excellent opportunity to study a situation of long standing wherein a great abundance of smallmouth bass had long yielded generally poor angling returns.

Results from a scientific investigation, conducted mostly during the summer of 1940, were as follows:

(1) A somewhat radical angling method was developed which yields greatly increased and highly satisfactory returns from the bass population.

(2) The discovery that shifts in habitat—both diurnal and otherwise—by particular age groups of the smallmouth bass population had a significant effect upon angling returns.

(3) The discovery that the smallmouth bass population of the lake was heterogeneous in character, i.e. that bass from one section of the lake had a significantly more rapid rate of growth than bass from another section, and that this influenced the quality of catch.

(4) The conclusion that the smallmouth bass problem of Lake Simcoe cannot be solved by stocking; but rather by the dissemination of knowledge on improved methods of utilization.

Introduction

Contrary, perhaps, to popular conception, fishery problems are often concerned with situations of abundance and the need for discovering new techniques or methods that can more fully utilize a particular resource. Among the many types of such problems of "wasted abundance" may be mentioned the following: (1) unsatisfactory size composition of the population; (2) potential uses unknown or unappreciated; (3) danger to health through use; (4) satisfactory techniques, or methods, of processing unknown or unappreciated; (5) unsuitable regulations; (6) poor availability or susceptibility, or both, to employed methods of capture.

The last mentioned type of problem (poor availability, etc.) to which Lake Simcoe belongs, is apt to be difficult of solution for at least two reasons: first, because a situation of abundance may—owing to the inefficiency of the methods of capture being employed—masquerade under an appearance of scarcity; secondly, because the development of techniques, or methods, that are at once practical and feasible, may entail the prospect of considerable time and experimentation without any assurance of eventual success. With luck and a bit of persistence, however, the results of such efforts may be worthwhile and useful, as is indicated by the present research.

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The Fishery Problem of Lake Simcoe

Lake Simcoe—Ontario's fourth largest lake—presents an interesting example of "scarcity midst abundance". It supports heavy populations of both lake trout and smallmouth bass, yet the former are caught in quantity (by angling) only during the spring of the year, while the latter are seldom taken consistently and in number except in the northern section of the lake by relatively few anglers (including professionally guided parties). This condition, which exists today, has endured during the memory of the senior author, which extends back prior to the year 1922.

The abundance of smallmouth bass in Lake Simcoe cannot very well be questioned, because in the Kempenfeldt Bay area, where angling returns for this species are possibly the poorest of any region of the lake, the water is so clear during the early part of the summer that fish can be observed at depths up to 10 ft. or more; and the number of smallmouth bass that can be seen by the careful observer is truly remarkable. On calm, sunny days, for instance, literally hundreds of legal-sized bass can sometimes be observed during an hour's slow trip in a power boat, distributed singly or in groups of two or more, over the extensive areas of sandy and stony littoral. An additional opportunity to witness the density of these fish in the Kempenfeldt Bay area is afforded during the flights of the mayfly, *Hexagenia* sp., usually during the early part of July. On these occasions, one can make a leisurely trip by power boat along the southern shore of Kempenfeldt Bay, from Lovers' Creek to Big Bay Point (see Fig. 2), and seldom be out of sight of smallmouth bass feeding upon these mayflies.

As previously indicated, the smallmouth bass in Lake Simcoe have a very poor susceptibility to conventional methods of angling, except within certain localities at particular times of year. And even in these areas, experience and special knowledge, such as that possessed by a few professional guides, have been necessary for consistent results. During 14 summers prior to 1939, for example, the senior author, aware of an abundance of bass in the Kempenfeldt Bay area, experimented with a wide variety of baits and commercial lures, but could never catch smallmouth bass in any number or with any degree of consistency. The best returns resulted from trolling during very cloudy days or late evening, but even these rewards were few and far between.

It was perhaps inevitable that under such circumstances Lake Simcoe should have early attained the reputation of being a "poor bass lake", and that the generally poor angling returns should have been widely interpreted as conclusive evidence of population scarcity. Rawson (7), for example, concurred in this conclusion, although he correctly reported the lake trout problem as being one of poor availability to angling methods during the summer months. (It is interesting to note that while Rawson (7) recommended the stocking of smallmouth bass and rainbow trout as solutions to these problems, both these measures appear highly undesirable in the light of the present research.)

Since the fishery problem of Lake Simcoe was so obviously one of inadequate methods of utilization, the writers decided, in 1939, to make intensive efforts toward developing effective angling methods for taking the smallmouth bass and lake trout; and, if successful, to conduct careful studies of these populations during the season of 1940; to be followed in subsequent years with checks upon results from the continued use of such angling methods or any modifications of same that might be developed.

Description of the Lake

Lake Simcoe is situated in gently rolling land of glacial moraine origin, about 40 miles north of the city of Toronto. The general shape and large size of the lake may best be understood by examining the map (Fig. 1). The

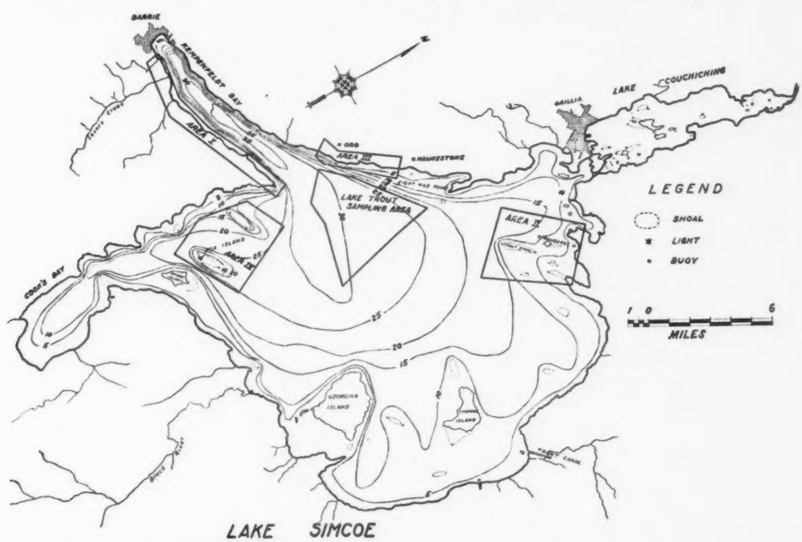

FIG. 1. *Map of Lake Simcoe, Ontario. The depth contours, in meters, are after Rawson (7) but have been slightly modified.*

surface area exceeds 275 square miles and the shoreline is more than 140 miles in length, including islands. The position of the lake has made it a connecting link in the Trent Valley system of waterways, which provides a navigation route from Lake Ontario to Georgian Bay. The elevation of Lake Simcoe is 720 ft. and its natural drainage is into Georgian Bay by way of Lake Couchiching and the Severn River. The connection between Lakes Couchiching and Simcoe is a narrows through which flows a considerable volume of water.

The water of the lake may be described as blue-green and clear, being similar in appearance to the waters of New York's finger lakes. During late July, August, and early September, the clarity of the water in Kempenfeldt

Bay (as measured by distances of bottom visibility) appears to be nearly twice that of the water in the northern section of the lake. The bathetic character of Lake Simcoe is shown by the map (Fig. 1).

Lake Simcoe may be considered as intermediate in type between the eutrophic and oligotrophic categories. Rawson (7) has termed it "an eutrophic lake with an oligohumus bottom". There is a moderate stratification of water during the summer months when the bottom temperatures in the deeper sections may range from 9° to 14° C. and when the dissolved oxygen content near the mud, according to Rawson (7) may be as low as 2.0 p.p.m.

Of particular interest is the character of the shoreline and the presence of extremely large shoals, some of which are more than a mile in length. Rawson (7) has grouped the various types of shoreline as follows: 54% stony; 33% sand; 13% vegetation. The shoals are mostly gravel to boulder in character, except when forming shelves along the shoreline, in which case they may be sandy with patches of weed beds. The gravel, rubble, and boulders are chiefly limestone and have been worn smooth by erosion. Boulders are frequently large-sized, sometimes exceeding 8 ft. in diameter.

Procedure

Briefly outlined, the experimental procedures may be listed as follows:

1. The development of an effective angling gear and method.

2. The establishment of sampling areas in different parts of the lake, and the procurement and study of samples of the bass population from these areas.

3. The consistent use of the developed angling method throughout the summer of 1940 in one of the sampling areas.

4. The procurement of miscellaneous data on such phenomena as water temperatures, weather conditions, parasitism, spawning sites, etc.

The field investigations were made during September, 1939; from June 13 to Oct. 15, 1940; and again during a brief period in July, 1946. In addition, the developed angling method or modifications of same, or both, were used by other persons during the summers following 1940, and comment was received on the general results obtained from these angling efforts.

1. The Angling Method

A very effective angling method for taking Lake Simcoe bass was developed during September, 1939, after a series of discouraging experiments. It consisted essentially of trolling a bucktail streamer fly (of home design) and spinner in the wash of a power boat at a speed of approximately two to three miles per hour. The usual trolling distance of the lure was from 35 to 60 ft. astern, and it was early discovered that the bucktail fly should never be permitted to spin if good results were to be obtained.

Two bucktail flies, each of a different color pattern, were found to be equally effective. One of these flies may be described as follows: It possessed a

lemon-yellow, chenille body with red tail; a head of black thread tightly wound and varnished; and a layer of yellow bucktail hair covered dorsally by a layer of red bucktail. It was tied on a No. 5 long-shanked hook and differed importantly from commercial lures of its type by being streamlined, i.e. the hair was almost horizontal to the body when the fly was dry, and completely horizontal when being trolled.

The spinner was a No. 2 hammered brass, and a 31-in. leader of 8 lb. test synthetic gut was tied directly to the spinner shank, with the other end of the leader fastened to a small swivel. A No. 6 or 7 clamp sinker was fixed on the leader directly below the swivel. The line was 12.5 lb. test nylon, and it was discovered that if a coarser line was employed, a slightly heavier sinker was preferable.

The boat chiefly used for the smallmouth bass angling during 1940 was a 15 ft. yacht dinghy, powered by a 5 h.p. outboard motor equipped with a slow speed adjustment. This motor had an underwater exhaust, and it was surprising to note that lárge bass were sometimes taken when the lure was within 10 ft. of this exhaust and the revolving propeller. It was also interesting to discover that the casting of the same lure and rig noted above was singularly ineffective, even in spots where a number of fish would be taken a few moments later by the trolling method. This experiment was tried again and again with similar results, and it suggests that the wash of the propellor and boat were important factors in the efficiency of the method. This, of course, is not incredible when the apparent importance of "boat wash" to certain salt water trolling methods is considered. A small launch was also occasionally employed during 1940, and this craft seemed to be just as efficient as the outboard.

Experiments by other persons after the summer of 1940 revealed that small plugs of the diving type could also be trolled with considerable success, and this modification is now preferred by some in the belief that it is selective for the larger bass. It also yields good returns when a paddled canoe is used.

During the 1940 experiments, all trolling was done within the last five and one-half hours of daylight. This meant that at the beginning of the summer, a day's angling did not cease until approximately 9:10 P.M. Eastern Standard Time, when daylight had diminished to a point where reading ordinary newsprint was extremely difficult. The number of lines trolled simultaneously was usually two (by two persons) although as many as four lines (by four persons) were trolled on occasion. Throughout the entire period of study, all angling methods, procedures, and operations were made to conform with the official regulations that governed the taking of smallmouth bass in these waters.

2 and 3. Areas and Sampling Procedures

Four reference areas were set up for population sampling (Fig. 1). Of these, Area I was subdivided into six zones (Fig. 2). This particular area differs from the others by possessing a shore shelf which extends, almost uninterrupted, along its entire length. This shelf varies in composition from

sand, with weed patches, to boulders, and has a maximum depth of approximately 15 ft. The outer edge of the shelf, where the lake deepens suddenly, has intermittent weed beds of *Potamogeton* sp. It was possible to troll this shelf to within a few feet of the shore, where the water is approximately 2 ft. deep.

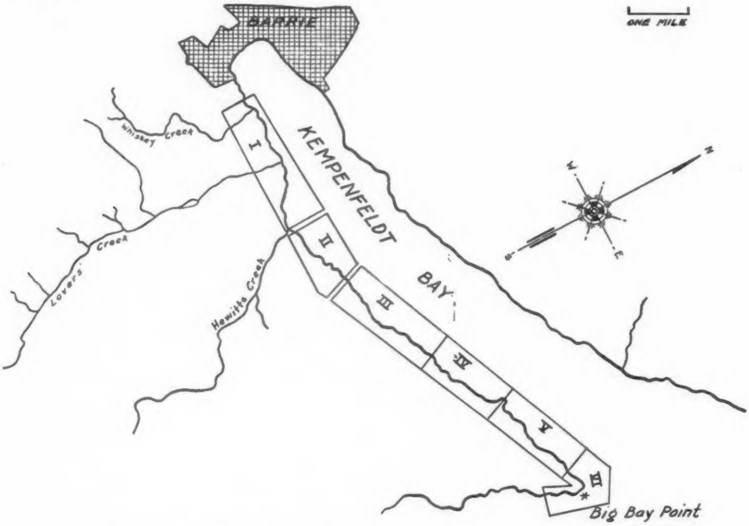

FIG. 2. *Map of Kempenfeldt Bay showing the subdivision of Area I into six zones.*

Area III has a comparatively narrow shore shelf of rubble and boulders with an occasional sandy region. No weed beds were noted in this area.

Areas II and IV possess large shoals whose depths generally range from about 18 in. to 20 ft. The shoals in the latter area, and some in the former area, are much exposed to wave action, as can be seen from Fig. 1.

Area I was fished intensively during July, August, and part of September, 1940, when the trolling method was used exclusively. Owing to weather conditions, it was not practical to sample this area every day during the period in question, but a total of 30 fishing days were accounted for during July and August. Area II was sampled on three days during August and on two days in September, when both trolling and bait fishing methods were employed. The two remaining areas were fished from time to time during the summer by the trolling method, more in an attempt to determine angling conditions than to obtain samples for comparative study.

Data on the fish from the various sampling areas were obtained as follows. The lengths of the specimens were measured from snout to center of tail to the nearest half-centimeter. Scale samples were taken from two regions of the body: from a small area on the side just posterior to the tip of the relaxed

pectoral fin (approximately 16 scales), and from the side just above the lateral line and ventral to the soft dorsal fin. Scales were taken from the second region merely to ensure a reserve sample in the event that the scales from the first region proved to be regenerated. Weights of sublegal-sized fish were obtained directly after scale sampling and measuring, whereupon these small specimens were returned to the water. Weights of those larger fish that were not returned to the water were always obtained within five hours from the time the specimens were taken; and those smallmouth that were killed and retained were always kept in a moist condition until weighed. All weights were obtained to the nearest half-ounce by means of a postal spring scale that had a capacity of four pounds. Stomachs were removed from the retained specimens, immediately after the weights were recorded, and were then wrapped in cheese cloth, labelled, and placed in 10% formalin for future study.

A total of 105 of those bass that were caught and returned to the water in Area I during the period July 4 to Aug. 19 were marked by fin clipping. This experiment will not be reported upon fully because of the small number of returns. However, those returns that were obtained tended to demonstrate that fins clipped in the manner employed for this experiment would not regenerate.

4. Miscellaneous Observations

Bottom and surface temperatures were taken in the several zones of Area I from time to time throughout the season of 1940. Temperatures were also taken in Zone I during a two week period directly preceding the opening of the angling season.

Results

Results of Angling in Area I, and Analysis of Catch

It has been previously indicated that the angling effort expended in Area I was for three main purposes: first, to demonstrate an angling method that would yield excellent results as viewed by fishermen; secondly, to reveal changes (if any) in the susceptibility or availability of the bass population to this angling procedure; and thirdly, to obtain samples of the bass population in all the zones throughout the period in question. The angling effort, therefore, was not devoted toward obtaining the maximum number of fish per effort from the best sections of the area. It would have been a simple matter, for instance, to have concentrated any day's angling to the zone or place where the most fish had been caught previous to that day. However, all the zones received attention regardless of the angling results obtained. It should be re-emphasized, moreover, that Kempenfeldt Bay, where Area I was situated, has possibly the poorest reputation for bass angling of any region in the entire lake. Consequently, the results of the angling effort in this area should be regarded in the light of several mitigating factors.

During July and August, a total of 197 bass were taken in Area I. The 15 angling days in July accounted for 117 of these fish while an equal number of days of angling in August produced only 80. Six fishing days in September

accounted for only four bass, and two days of angling in October failed to produce any catch.

The lengths of the fish taken during July and August (Table I) have been plotted by their percentage frequency of occurrence in Fig. 3. The age

TABLE I

LENGTHS OF SMALLMOUTH BASS TAKEN IN AREA I DURING JULY AND AUGUST, 1940

Length, $\frac{cm.}{2}$	No. fish, July	No. fish, August	Length, $\frac{cm.}{2}$	No. fish, July	No. fish, August
26	0	0	55	2	1
27	1	0	56	5	0
28	0	0	57	5	2
29	1	0	58	4	1
30	0	1	59	2	2
31	3	0	60	3	0
32	1	1	61	3	0
33	0	0	62	1	1
34	1	3	63	4	1
35	0	0	64	3	1
36	0	3	65	1	0
37	1	5	66	0	0
38	3	1	67	0	0
39	4	2	68	2	0
40	7	2	69	3	0
41	4	3	70	4	0
42	1	8	71	2	1
43	5	6	72	1	1
44	4	5	73	3	2
45	2	11	74	3	2
46	1	4	75	1	0
47	5	1	76	1	0
48	1	3	77	3	0
49	1	0	78	1	0
50	1	1	79	0	0
51	3	1	80	0	0
52	1	2	81	1	0
53	5	1	82	0	0
54	3	1			

composition of this catch is also revealed by Fig. 3. A study of these graphs immediately suggests that a change in susceptibility or availability of the larger fish (those of four years of age and over) took place during the period in question. Only 20 fish over the legal size limit, or approximately 25% of the August catch, were taken during that month; while 70 legal-sized bass, or approximately 60%, were taken during the July period. These data, however, do not reveal the entire picture because more than half of the 20 legal fish that were taken during August were caught in much deeper water and nearly always in weed beds of *Potamogeton* sp. When only those fish that were taken from similar habitat are considered, there is less than one chance in one hundred (based upon Chi square) that the difference in catch of these larger fish between July and August was due to chance. This drop in catch was

sudden and took place during the first few days of August, when it was also noted that there was a rapid decrease in the number of bass that could be seen from the boat. In fact, a legal-sized fish was seldom seen in the "July"

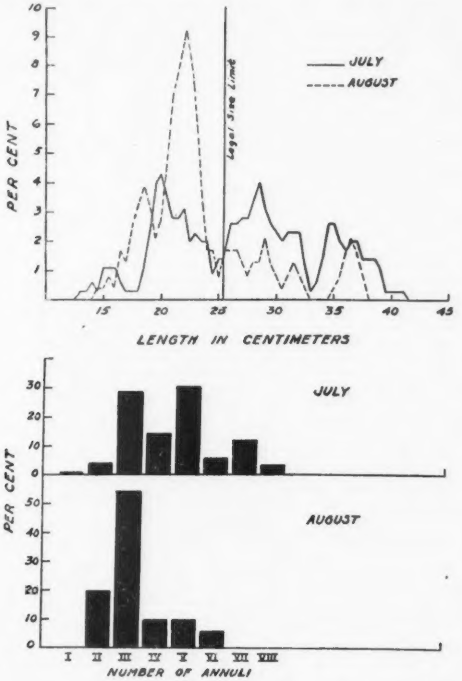

FIG. 3. (*Upper*) *Lengths of smallmouth bass taken from Area I during July and August, 1940, plotted by their percentage frequency of occurrence. These data have been smoothed once by a moving average of threes.*
(*Lower*) *Age composition of bass taken from Area I during July and August, 1940.*

area after Aug. 3, and, as previously mentioned, the majority of those fish that were caught in Area I after this date were taken from the deeper waters and in weed beds, particularly along the outer margins of the shelf. Finally, the remaining legal-sized fish that were caught during August, in this Area, were, without exception, taken within the last hour of daylight.

The fact that the larger bass were most frequently taken in weed beds during August is of interest, because the adults of this species are often believed not to frequent such a habitat, when rocky areas are available. For example, Hubbs and Bailey (6) have stated that adult smallmouth "are rarely taken near beds of submerged or floating plants". Yet the instance noted here is not at all exceptional for Lake Simcoe; and in Lake Couchiching, in particular, the presence of adult smallmouth bass in weed beds is a common occurrence, especially during the months of August and September. In Area II,

also, bass are frequently taken from beds of ***Potamogeton*** sp., and are sometimes purposely fished for in this type of habitat by professional guides.

The one-year-old age class of bass (average length undetermined) and most of the two-year-old fish (average length 30.8 half-centimeters in July and 36.5 $\pm$ .83 for August) were taken in regions of large boulders, docks, and sunken cribs. The depth of water in these instances varied considerably: from about 3 to 20 ft. The three-year-old fish (average length 41.2 $\pm$ .48 half-centimeters for July and 43.5 $\pm$ .38 for August) were usually taken in quiet, shallow water and very close to the shoreline. Hence there appeared to be several types of habitat occupied by smallmouth bass in Area I, with the particular habitat selected usually depending upon the age of the fish, the time of year, and the time of day. The presence of legal-sized smallmouth on the shelf region of Area I during mornings and afternoons, however, is not necessarily limited to the early part of summer. During September of 1939, for example, excellent catches from the shore shelf were made during daytimes, and similar returns were obtained during the years following 1940. Further, it has been noted that the relative "productiveness" of the several zones may change from one year to another.

The fact that the fish of the older age classes changed their habitat at approximate midsummer during 1940, leads to the consideration of possible causes for this phenomenon. Since all the legal-sized fish examined were adults, it was first suspected that spawning activity was concerned in the habitat change. It is true that the fish taken during July were caught in spawning regions. This was revealed by the presence of nesting sites, particularly in Zone III, which were generally located at depths of from 6 to 10 ft. However, only two of these nests were observed to be possibly occupied by adult fish after July 1.

Whether or not male bass were guarding young during July 1940 is a matter of question; but the fact that adult females were also present in the region during this time is shown by the records. Of the 49 sexed fish taken during July, for instance, 27 were males and 22 were females. Based on Chi square, the probability is approximately one to one that this sample is a fifty-fifty distribution of males and females. There was also no significant difference between the number of males and females taken during the first 16 days of July, when the sexed fish included 18 males and 13 females, nor during the last 15 days of July when nine males and nine females were examined. The change in habitat by the adult fish did not alter this sex distribution of the catch, since the August sample included 10 males and nine females.

These data would indicate that the parental care of nest or young, if present at the time, did not influence the sex distribution of the catch. Supplementing this observation is the fact that the type and action of the lures used was very influential in determining angling results for both the adult male and female fish. It seems probable, therefore, that the striking of the lure was not a protective response on the part of guarding male bass.

The cause for the decrease in catch of sublegal-sized bass during September seemed to be one of change in susceptibility. These fish appeared not to have changed their habitat during this time, yet catches by the trolling method were very low.

Growth Rates in Area I

The examination of the scales from fish taken in Area I indicated that the 1940 annulus was laid down during the late spring or early summer. Scales from most of the fish taken during the first two weeks of July did not have a clearly defined annulus at the periphery. The 1940 annulus, however, had become well defined by the fourth week of July. In the reading of the scales, this 1940 annulus was always included whether or not it was clearly defined on specimens taken during the early weeks of the season.

The age–length relationships of bass taken in Area I during July and August have been plotted in Fig. 4 by the method employed by Westman and Fahy (10) and Westman and Gilbert (11). The growth rates in Fig. 4 make no distinction between male and female fish, and, owing to the fact that the rates are used comparatively, it is desirable to know whether or not there are significant differences of growth rate between the sexes of these fish.

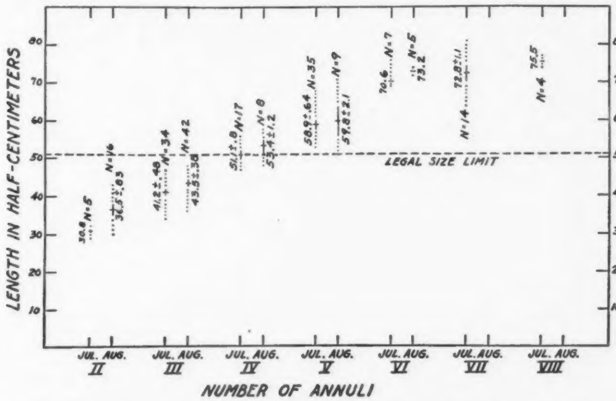

FIG. 4. *Age–length relationships of smallmouth bass taken from Area I during July and August, 1940. The solid line represents twice the standard error of the mean in both the plus and minus directions. The broken line represents the limits of variation found in the sample. The means, with their standard errors, and the numbers of specimens are also given numerically.*

Comparisons in the growth rate of the male and female bass from Lake Simcoe were, by necessity, limited to the five-, six-, and seven-year-old fish. Accordingly, the lengths of male and female bass of three age classes, taken from Area I during the period from July 4 to Aug. 16 (Table II), were transformed into three-place logarithms and compared by means of an analysis of variance. The results are as follows:

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	35	0.093615	
Age	2	0.071961	0.035980
Sex	1	0.000221	0.000221
Age-sex interaction	2	0.004927	0.002463*
Within subclasses	30	0.016506	0.000550

TABLE II

LENGTHS, IN HALF-CENTIMETERS, OF MALE AND FEMALE SMALLMOUTH BASS OF THREE AGE CLASSES TAKEN IN AREA I DURING THE PERIOD JULY 4 TO AUG. 16, 1940. THE DATA HAVE BEEN MADE PROPORTIONATE BY RANDOM SUBSAMPLING

No. of annuli					
V		VI		VII	
Male	Female	Male	Female	Male	Female
56	54	69	70	71	81
60	58	70	73	70	77
64	61	69	74	72	74
58	61	72		64	
62	57	74		68	
57	52	73		73	
58					
63					
59					
51					
64					
59					

No significant difference between the growth rate of the males and females is indicated by the foregoing analysis. There is, however, a significant age-sex interaction which suggests that differences may exist at particular times in life.

A comparison of 13 male and 19 female bass of the five-year-old class taken during the period from July 4 to Aug. 16 (Table III), gives an F value of zero, with the difference between the means of the non-transformed data being only 0.03 half-centimeters.

In dealing with the growth rates of male and female bass from Perch Lake, Ont., Tester (9) states: "The results, given in table 5, show that, on the average, female bass of Perch Lake grew at a slightly slower rate than the male bass." This statement has been mentioned by Greeley (2) and Bennett (1). A study of Tester's data, however, reveals the fact that his conclusions rest upon single averages, with normal variations due to chance not accounted for. This fact, particularly when the extent of variability in bass of the younger size groups is considered, apparently makes any significant differences of growth rate between the sexes yet to be demonstrated.

TABLE III

LENGTHS, IN HALF-CENTIMETERS, OF FIVE-YEAR-OLD MALE AND FEMALE SMALLMOUTH BASS TAKEN IN AREA I DURING THE PERIOD JULY 4 TO AUG. 16, 1940

No. of annuli			
V			
Male	Female	Male	Female
56	61	51	53
60	54	64	58
64	57	59	61
58	60		58
62	58		57
57	57		57
58	63		71
63	61		52
59	65		62
59	61		

Further attempts toward determining whether or not there are significant differences in growth rate between male and female bass during the early years of life were made as follows: From the published data of Tester (9), Greeley (2), Greeley (3), Greeley (4), Greeley (5), and Bennett (1), the mean lengths of male and female bass from various lakes were compiled, combined, and compared. The mean lengths of two-, three-, and four-year-old fish from seven lakes (see Table IV) were first taken, transformed to logarithms and analyzed. The results of the analysis of the variance are as follows:

TABLE IV

MEAN LENGTHS, IN MILLIMETERS, OF TWO-, THREE-, AND FOUR-YEAR-OLD MALE AND FEMALE SMALLMOUTH BASS FROM SEVEN LAKES, AS COMPILED FROM THE PUBLISHED DATA OF TESTER (9); GREELEY (2, 3, AND 5); AND BENNETT (1)

	No. of annuli					
	II		III		IV	
	Male	Female	Male	Female	Male	Female
Tester (9)						
Perch Lake	146	137	173	169	212	201
Bennett (1)						
Nebish Lake	179	177	213	226	270	239
Pallette Lake	176	173	229	196	249	235
Greeley (2)						
Raquette Lake	146	168	208	187	223	243
Duck Lake	166	156	192	189	216	212
Greeley (3)						
Gilboa Reservoir	182	184	247	206	273	249
Greeley (5)						
Kensico Reservoir	151	169	248	235	281	281

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	41	0.283413	
Age	2	0.193280	0.096640
Sex	1	0.001723	0.001723
Situation (time, place, and method)	6	0.064078	0.010680
Error	32	0.024332	0.000760

No significant difference in growth rate between males and females having been shown by the above, the mean lengths of two-, and three-year-old males and females from 12 lakes (Table V) were then compared in similar fashion:

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	47	0.345547	
Age	1	0.091700	0.091700
Sex	1	0.000075	0.000075
Situation	11	0.213691	0.019426
Error	34	0.040081	0.001670

Here again no significant difference is shown to exist between the growth rates of the male and female bass.

TABLE V

MEAN LENGTHS, IN MILLIMETERS, OF TWO- AND THREE-YEAR-OLD MALE AND FEMALE SMALL-MOUTH BASS FROM 12 LAKES, AS COMPILED FROM THE PUBLISHED DATA OF TESTER (9); GREELEY (2, 3, 4, AND 5); AND BENNETT (1)

	No. of annuli			
	II		III	
	Male	Female	Male	Female
Tester (9)				
Perch Lake	146	137	173	169
Bennett (1)				
Nebish Lake	179	177	213	226
Pallette Lake	176	173	229	196
Muskellunge Lake	187	185	229	241
Greeley (2)				
Raquette Lake	146	168	208	187
Duck Lake	166	156	192	189
Simon Pond	224	256	225	280
Tupper Lake	215	207	265	286
Forked Lake	133	128	159	171
Greeley (3)				
Gilboa Reservoir	182	184	247	206
Greeley (4)				
Lake Huntington	231	220	221	241
Greeley (5)				
Kensico Reservoir	151	169	248	235

From all the foregoing analyses, it seems evident that if differences in growth rate between the sexes do exist, then such differences are very slight and are perhaps confined to the older age classes. For this reason there seems to be no necessity for considering the growth rates of the male and female bass from Lake Simcoe in separate categories.

In order to determine whether significant differences of growth rate existed between bass from different regions of Area I, a comparison of the growth rates of fish from Zones I and II, taken during the period from July 24 to Aug. 20, was made with the fish from Zones V and VI taken during the same

TABLE VI

LENGTHS, IN HALF-CENTIMETERS, OF TWO-, THREE-, FOUR-, FIVE-, AND SIX-YEAR-OLD SMALL-MOUTH BASS TAKEN FROM ZONES I AND II, AND FROM ZONES V AND VI, DURING THE PERIOD JULY 24 TO AUG. 20, 1940. THE DATA HAVE BEEN MADE PROPORTIONATE BY RANDOM SUBSAMPLING

No. of annuli									
II		III		IV		V		VI	
Zone I & II	Zone V & VI	Zone I & II	Zone V & VI	Zone I & II	Zone V & VI	Zone I & II	Zone V & VI	Zone I & II	Zone V & VI
37	31	42	48	55	54	57	58	73	69
36	30	43	42	58	50	51	57	74	73
34	32	44	44			71	59		
		45	46			58	62		
		38	44						
		39	41						
		42	41						
		45	45						

period of time. Accordingly, the lengths of the two groups of fish (Table VI) were transformed into three-place logarithms and the significance of difference determined by means of an analysis of variance. The results are as follows:

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	37	0.425064	
Age	4	0.394615	
Place	1	0.000295	0.000295
Age–place interaction	4	0.006797	0.001699
Within subclasses	28	0.023357	0.000834

No significance of difference between the growth rates of the two groups of fish is demonstrated by the above and, consequently, when the rate of growth is used as the criterion, no evidences of population heterogeneity in Area I were found.

Results of Angling in Area II, and Analysis of Catch

During 1940, angling in Area II was done on Aug. 21, 23, 24, and on Sept. 16 and 22. The use of the trolling method was confined to Aug. 24 and Sept. 16 and 22, when its success was limited to the last hour of daylight. On the first two trolling days, a total of 11 bass were caught—all legal-sized fish which ranged in weight from 12 oz. to 3 lb., 3 oz., and which had an aggregate weight of 21.5 lb. The trolling on Sept. 22 yielded no fish, and, according to the professional guides, this was due to the usual fall "disappearance" of bass from the Area II shoals which "had taken place a few days previously". Approximately four hours of bait fishing with two lines on Aug. 21, and another four hours with five lines on Aug. 23, yielded a total of 39 fish, 20 of which were legal-sized and ranging up to two-and-one-half pounds in weight. It seems probable that a greater experience and familiarity with Area II would have yielded even more successful angling results than those that were obtained. The trolling method had not been employed by us in this area previous to the sampling days.

The catch from Area II was made up of fish from two-plus to eight-plus years of age, the eight-year class consisting of four bass that were 80 or more half-centimeters in length and that averaged 3 lb. in weight. The length–age relationships of the fish taken in Area II during August and September (Table VII) have been plotted in Fig. 5.

TABLE VII

Lengths, in half-centimeters, of smallmouth bass taken in Area II on Aug. 21, 23, and 24; and on Sept. 16, 1940

No. of annuli						
II*	III*	IV*	V*	VI*	VII*	VIII**
42	51	56	66	67	79	80
43	48	53	57	76	81	83
41	44	57	62	73		84
35	43	57	68	72		88
40	45	62	65			
38	44	66	59			
39	53					
36	56					
39	57					
34	51					
41	53					
	51					
	42					
	45					
	49					

* *August specimens.*
** *September specimens.*

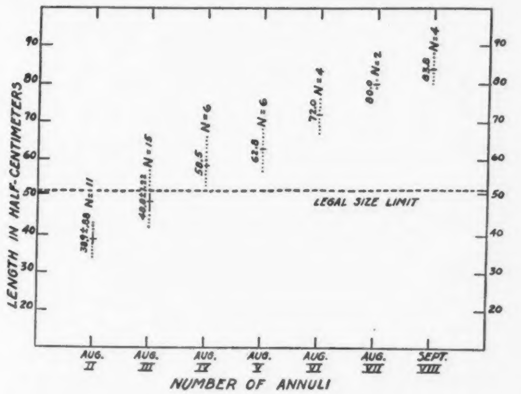

FIG. 5. *Age–length relationships of smallmouth bass taken from Area II. (For explanation of figure, see Fig. 4.)*

Results of Angling in Other Areas

Area III was trolled for approximately three hours on July 10, for one hour on Aug. 9, and for a half hour on Aug. 21. A total of 28 bass were taken on the three sampling days, 10 of these fish being of legal size. The July 19 catch contained four females and one male; and the Aug. 21 catch, one female and one male. A considerable number of very large bass were seen in this area, although only one was hooked.

Area IV was trolled twice during August, with a total fishing effort of approximately two hours. Thirteen bass were taken, five of which were over the legal size limit. This particular area was not fished during the last two hours of daylight.

A Comparison of the Growth Rates of Bass from Areas I and II

A comparison of Figs. 4 and 5 immediately suggests that the bass in Area II have a considerably faster growth rate than the fish in Area I. The legal size limit of 10 in., for example, cuts through the length range of the August three-year-old fish in Area II, while in Area I it falls above the range of the three-year-olds, sampled during the same month, but crosses the four- and five-year-old length ranges. That a significant difference in growth rates did exist between the bass of the two areas was demonstrated by testing the significance of difference between the lengths of the 15 three-year-old bass taken in Area II, during August, with the 19 fish of the same year-class taken in Area I during the last two weeks of the same month. In testing the significance of difference, the lengths of the two groups of fish (Table VIII) were first transformed into three-place logarithms and then compared by means of an analysis of variance. The results are as follows:

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	33	0.052468	
Area	1	0.016711	0.016711**
Error	32	0.035757	0.001117

Since the probability is more than a hundred to one that the difference between the two groups is not due to chance, the question is now raised: "Have significant differences in the size of the two groups existed during their previous years of life?"

TABLE VIII

LENGTHS, IN HALF-CENTIMETERS, OF THE 15 THREE-YEAR-OLD SMALLMOUTH BASS FROM AREA II AND THE 19 THREE-YEAR-OLD BASS FROM AREA I, TAKEN DURING THE LAST TWO WEEKS OF AUGUST, 1940

Area I	Area II	Area I	Area II
45	51	45	53
45	48	45	51
48	44	38	42
43	43	46	45
45	45	42	49
45	44	44	
43	53	46	
42	56	41	
44	57	41	
46	51		

TABLE IX

DISTANCE READINGS OF ANNULI FROM THE SCALE FOCI FOR THREE-YEAR-OLD SMALLMOUTH BASS TAKEN FROM AREAS I AND II DURING THE LAST TWO WEEKS OF AUGUST, 1940. THE DATA HAVE BEEN MADE PROPORTIONATE BY RANDOM SUBSAMPLING

Specimen No.	No. of annulus					
	I		II		III	
	Area I	Area II	Area I	Area II	Area I	Area II
1	25.5	29.5	44.5	54.0	61.5	77.5
2	19.5	29.5	39.0	43.0	54.0	61.5
3	18.5	31.5	45.5	58.5	62.0	80.0
4	18.5	33.0	44.0	52.5	66.0	75.0
5	19.5	18.5	44.5	39.5	64.0	60.0
6	17.5	33.5	38.0	49.0	53.0	67.0
7	19.0	24.5	46.5	48.5	56.0	68.5
8	17.5	26.0	34.0	51.5	55.5	74.0
9	24.0	24.0	50.0	41.0	63.0	62.5
10	23.5	23.5	52.0	48.5	70.5	70.5
11	21.0	25.0	38.5	47.0	59.0	62.5
12	24.0	27.5	46.0	47.5	56.0	80.0
13	20.0	31.0	42.0	61.0	64.5	89.5
14	24.5	23.5	47.5	56.5	65.0	94.5
15	20.0	24.0	40.0	49.0	63.0	73.0

This problem was solved in the following manner: First, the largest scale from each "pectoral" scale sample (see Sampling Procedures) of these three-year-old bass was carefully mounted in a medium of white Karo syrup. Second, each of the mounted scales was projected on a ground glass screen at a fixed magnification of approximately 33 diameters. Third, a millimeter ruler was placed across, and through the center, of the projected scale image, i.e. from one side of the scale to the other. Fourth, the distance from the focus to each of the three annuli on the scale was read to the nearest millimeter. This meant that two measurements for each annulus were obtained, one on each side of the focus. Fifth, the two measurements for each annulus were averaged together and the result recorded in Table IX. And, sixth, the values in Table IX were transformed into two-place logarithms and the significance of difference between the annulus distances of the fish from the two areas was tested by means of an analysis of variance. The result is as follows:

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	89	3.5595	
Annulus groups	2	3.1480	1.5740
Area	1	0.1537	0.1537**
Annulus group-area interaction	2	0.0026	0.0013
Within subclasses	84	0.2552	0.0030

A highly significant difference having been demonstrated to exist between the means of the two area groups when considered collectively, there remains to be tested the significance of the difference between the means of the two groups when they are considered under each separate annulus group. This has been done by the method exemplified by Snedecor (8) for testing the significance of difference when only a single degree of freedom is involved. The results are as follows:

Mean square $\frac{(S_1 - S_2)^2}{2k}$	Annulus group		
	I	II	III
	.0908*	.0282*	.0441*

This analysis shows that a significant difference also exists between the means of the two area groups when any one of the three annulus groups is considered individually.

If, therefore, these annuli distances are reliable and comparable indicators of previous length increments in the fish, then significant differences between the lengths of these two groups of fish existed at one, two, and three years of age.

Miscellaneous Observations

1. Analysis of Stomach Contents

Although qualitative and quantitative studies were made of the stomach contents of bass taken from the several areas throughout the summer of 1940, these will not be fully reported upon because of the highly doubtful value of the quantitative data. It was repeatedly observed, for example, that smallmouth bass, when hooked, would begin to regurgitate food; and if there was any greater tendency for the smaller particles, such as crayfish remains, to be retained—and this does not seem unlikely—the possible effects upon quantitative data are obvious. Also, the diurnal shifts in habitat already noted might well affect the stomach contents.

It may be stated, however, that during the summer of 1940, the smallmouth bass in Lake Simcoe apparently fed heavily upon crayfish and, perhaps to somewhat lesser extent, upon small fish, including: yellow perch (*Perca flavescens*); log perch (*Percina caprodes*); darters (*Boleosoma nigrum*); and sculpins (*Cottus bairdii*). It was interesting to note that despite the common occurrence of spot tailed minnows (*Notropis hudsonius*), and blunt nosed minnows (*Hyborhynchus notatus*) near the shoreline in Area I, these species were not found in the stomachs of those adult smallmouth that were examined. It seems possible, however, that the sublegal-sized bass might have been feeding upon these minnows.

2. Parasitism

With a single exception, all those bass that were killed and retained showed the visceral adhesions generally associated with an infestation of bass tapeworm (*Proteocephalus ambloplites*). In most instances, plerocercoids could be found with but little difficulty and in many cases the infestation was extremely marked. It would be difficult to determine, of course, what effect this infestation has upon the fertility of the bass population in Lake Simcoe; but it should be emphasized that this parasite does not affect the health of man and that its effect upon the edibility of the fish is confined to possible objections upon aesthetic grounds.

In addition to the foregoing, three bass were taken during 1940 that showed lesions typical of lamprey attack.

3. Water Temperatures in Area I

Throughout the summer of 1940, bottom and surface temperatures were taken, from time to time, in the shelf region of Area I. On calm days, the bottom temperatures were always found to be slightly lower than surface readings. A slight chop, however, appeared to be all the agitation necessary to give similar temperatures at surface and bottom. These temperatures have been recorded in Table X.

TABLE X

Bottom temperatures, to the nearest half-degree centigrade, taken in Area I during the period June 14 to Sept. 27, 1940

Date	Zones					
	I	II	III	IV	V	VI
	Temp.					
June 14	19.0					
June 17	12.0					
June 19	14.0					
June 21	9.5					
June 30	11.0					
July 1	13.0					
July 2	12.5					
July 3	15.0					
July 4	17.0	—	16.5	16.0		
July 5	17.5	17.0	17.0	17.0		
July 6	15.0	15.5	—	—		
July 7	18.0	—	—	—		
July 8	17.0	17.5	19.0	19.0	19.0	
July 9	18.5	—	—	—	—	
July 10	—	—	—	—	19.0	
July 12	—	17.0	17.0	—	—	
July 14	18.0	19.0	18.5	—	—	
July 16	—	—	20.0	19.0	19.0	
July 18	19.0	20.0	20.0	19.0	—	
July 20	20.5	21.0	20.5	—	—	
July 23	—	21.0	—	—	—	
July 24	—	26.0	25.5	25.0	24.5	
Aug. 1	—	22.0	21.5	—	—	
Aug. 7	—	23.0	23.5	—	—	
Aug. 10	—	—	—	22.0	—	
Aug. 19	22.0	—	22.0	—	—	
Aug. 20	21.0	—	21.0	21.0	21.5	21.5
Aug. 27	18.5	19.0	—	19.0	20.0	—
Aug. 31	19.0	—	—	—	—	—
Sept. 1	—	20.0	—	—	—	—
Sept. 19	17.0	18.0	18.0	—	—	—
Sept. 27	15.0	15.5	16.0	—	—	—

Results of Angling since 1940

As indicated in earlier paragraphs, several persons who are either summer or permanent residents at Lake Simcoe have employed the trolling technique and procedure—sometimes with modifications such as substituting small plugs of the diving type—in Area I during all the summers since 1940. On occasion, guests of these persons, who were neophytes in the art of angling, have also used the described method. While no catch records have been kept on these subsequent angling efforts, the reports received demonstrate that the effectiveness of the trolling technique has continued to remain highly satisfactory for those who employ it. In short, the veriest tyro can look forward to worthwhile bass fishing in Lake Simcoe if he uses the method and procedures described herein.

Of additional interest are reports that the same zones in Area I may not produce the best angling returns from one year to the next. Further, that the number of sublegal-sized bass taken may also vary greatly from one year to another.

Comments and Conclusions

Upon the basis of the investigations and observations reported herein, it is concluded that:

(1) The smallmouth bass problem in Lake Simcoe is one of poor susceptibility and availability of the bass population to the methods of angling commonly employed in the lake.

(2) The developed angling methods herein described can successfully solve this susceptibility–availability problem.

(3) Shifts in habitat—both diurnal and otherwise— by adult smallmouth bass may affect the availability and susceptibility of these fish to capture by angling methods, and hence influence angling returns.

(4) Smallmouth bass in the northern section of Lake Simcoe designated as Area II had a significantly faster rate of growth than bass in the Kempenfeldt Bay region designated as Area I; and this may affect the quality of catch.

(5) Little—if any—difference in rate of growth exists between male and female smallmouth bass in Lake Simcoe.

(6) The great majority of adult smallmouth bass in Lake Simcoe were, during 1940, infested with bass tapeworm, *Proteocephalus ambloplites.*

(7) The adult smallmouth bass in Lake Simcoe feed largely upon crayfish and upon young fish including *Perca flavescens*, *Percina caprodes*, *Boleosoma nigrum*, and *Cottus bairdii.* For a short period during early summer they also feed upon adults of the mayfly, *Hexagenia* sp.

(8) Sufficient evidence is not yet at hand for accurately predicting the occasional shifts in habitat that are made by the adult portion of the bass population. The existing evidence suggests, however, that there is a seasonal shift in habitat near midsummer and, sometimes, a return during late summer. This is suggested not only by the evidence as reported herein, but also by the fact that certain professional guides at the northern part (Area II) of Lake Simcoe often troll for bass during the early part of summer, in regions and habitats that are seldom fished after midsummer.

(9) Of equal interest is the evidence of late evening shifts in habitat by the adult bass. These late evening shifts are encountered in both Area I and Area II. In this latter Area, for instance, an extremely effective procedure for taking bass is to employ a bait method in certain "spots" on the shoals during the day, and troll the shallow waters of the shoals during the evening. It is necessary, however, to discover where some of these daytime "spots" are situated; and this can often be done by canvassing the shoals with the trolling method during the day for indications of available fish.

(10) In view of the paucity of bass anglers in Lake Simcoe—one seldom encounters a half-dozen outside of Area II—it would appear that a much

fuller utilization of the resource could be best accomplished through dissemination of knowledge on the improved methods of angling and on the habits of the fish as reported herein.

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